REMARKS

Further and favorable reconsideration is respectfully requested in view of the foregoing amendments and following remarks.

Claims 1 and 2 have been amended to make minor changes of an editorial nature. Therefore, no new matter has been added to the application.

The patentability of the present invention over the disclosure of the reference relied upon by the Examiner in rejecting the claims will be apparent upon consideration of the following remarks.

The rejection of claims 1 and 2 under 35 U.S.C. § 103(a) as being unpatentable over Sato et al. is respectfully traversed.

[Initially, although the rejection refers to claims 1-4, it is clear that claims 1-2 were intended, as these are the only pending claims in the application.]

The Examiner takes the position that Sato et al. teach a method of treating pure titanium or a titanium alloy by plasma carburizing at 0.5-15 Torr (66.66 – 2000 Pa). The Examiner further states that Sato et al. teach that the carburizing atmosphere was 100% propane, where H/C is 2.67. The Examiner asserts that Sato et al. teach an overlapping range for the pressure of the plasma carburizing treatment and an H/C ratio that is within the claimed range.

The Examiner admits that Sato et al. fail to meet the claimed temperature range for the plasma carburizing treatment. However, the Examiner asserts that the claimed temperature range would have been obvious to one of ordinary skill in the art because the prior art range is close enough that it would have been expected to have the same results. The Examiner states that Applicant can overcome the rejection by showing that the present invention produces results that are different from the closest prior art, i.e., Sato et al. with plasma carburizing at 700°C. As discussed below, Applicants' claimed invention does produce different results from the closest prior art.

Applicants' claims 1 and 2 require plasma carburizing in an atmosphere having a temperature of 400 to 690 °C, and require that the carburizing atmosphere comprises a carburizing gas having a molar ratio of hydrogen atoms (H) to carbon atoms (C) which is adjusted to $1 \leq H/C \leq 9$. It is especially important to carry out plasma carburizing at 690°C or less in an atmosphere where the molar ratio is $1 \leq H/C \leq 9$.

When plasma carburizing is performed at a temperature not exceeding 690°C, even if the molar ratio and the pressure of the carburizing gas are the same as when carrying out plasma carburizing at 700°C or higher, poor results are obtained. Specifically, ions tend to become amorphous and deposit on the surface in the form of soot or glass-like carbon instead of being carburized into a titanium metal (end product). (See page 3, lines 1-4 of Applicants' specification.)

In order to solve this problem, Applicants perform plasma carburizing at a low temperature of not more than 690 °C using a carburizing gas of which the molar ratio of hydrogen atoms (H) to carbon atoms (C) is adjusted to $1 \leq H/C \leq 9$. Thus, as in aging treatment (during carburizing), an α-layer deposits on the surface of the titanium metal in which α-type (hexagonal system) and β-type (regular system) structures coexist. Therefore, it is possible to turn many carbon atoms to solid solution on the surface to the limit of the α-type titanium metal at the predetermined temperature of plasma carburizing. (See page 4, last 3 lines to page 5, lines 1-4 of Applicants' specification.)

With this arrangement, a carburized layer comprising a carbonized metal layer will not deposit on the surface subjected to cleaning even at a low temperature, but carbon reliably penetrates into the crystal lattice to form a carburized layer. (See the paragraph bridging pages 5 and 6 of Applicants' specification.)

That is, soot or glass-like carbon does not deposit on the surface of the titanium metal. Instead, it is possible to form a relatively thick, durable, sliding treated surface on its surface. Thus, the friction coefficient and the wear amount can be reduced in a stable state. (See the paragraph bridging pages 13 and 14 of Applicants' specification.)

On the contrary, Sato et al. merely disclose that plasma carburizing is carried out in an atmosphere of 0.5 to 15 Torr and 700 to 1100 °C. Sato et al. is completely silent about plasma carburizing in an atmosphere of 400 to 690 °C or plasma carburizing in an atmosphere where the molar ratio is $1 \leq H/C \leq 9$. In fact, 100% propane gas, as used in Sato et al. for carburizing treatment, has a molar ratio H/C of 0.2, which is outside Applicants' recited range of $1 \leq H/C \leq 9$.

The molar ratio H/C is the ratio of the total weight of the hydrogen atoms to the total weight of the carbon atoms in one molecule of the gas used for carburization. In the case of 100% propane gas (C_3H_8), as used as a process gas for carburizing in Sato et al., the total weight

of the 3 carbon atoms in one molecule of C_3H_8 is 36 (3 multiplied by 12 (atomic weight of carbon)), and the total weight of the 8 hydrogen atoms in one molecule of C_3H_8 is 8 (8 multiplied by 1 (atomic weight of hydrogen)). Thus, the molar ratio H/C of 100% propane gas is 0.222 (8 divided by 36), and thus is much lower than the lowest limit of Applicants' recited range of $1 \leq H/C \leq 9$. In this regard, the Examiner's assertion that the molar ratio H/C of 100% propane gas C_3H_8 is 2.67 (8 divided by 3) is incorrect.

In Example 1 of Applicants' invention, since H_2 gas is used for dilution in addition to C_3H_8, the molar ratio is the ratio of the total weight of the carbon atoms in the process gas C_3H_8 to the sum of the total weight of the hydrogen atoms in the process gas C_3H_8 and the total weight of the hydrogen atoms in the diluting gas H_2.

The total weight of the carbon atoms in the process gas C_3H_8 is:

> Flow rate of C_3H_8 x (Total weight of the carbon atoms in C_3H_8 /Molecular weight of C_3H_8) = 20 x (36 / 44) = 16.36

The sum of the total weight of the hydrogen atoms in the process gas C_3H_8 and the total weight of the hydrogen atoms in the diluting gas H_2 is:

> Flow rate of C_3H_8 x (Total weight of the hydrogen atoms in C_3H_8 /Molecular weight of C_3H_8) + Flow rate of the diluting gas H_2 = 20 x (8 / 44) + 100 = 103.6

The molar ratio H/C of the carburizing gas used in Example 1 of the present invention is therefore 6.3 (= 103.6 / 16.36), which is within the recited range.

Thus, Sato et al. do not disclose a molar ratio H/C which is within the recited range. It is therefore apparent that it is impossible to turn many carbon atoms to solid solution on the surface to the limit of the α-type titanium metal to form a relatively thick, durable sliding treated surface on the surface of the titanium metal without the possibility of deposition of soot or glass-like carbon on the surface of the titanium metal.

Applicants enclose herewith a reference which indicates that it is known to carry out aging treatment at 690 °C or less separate from carburizing. Carburizing treatment is carried out separately from aging treatment at a high temperature exceeding 700 °C.

Thus, before the present invention, during carburizing, the effect of the aging treatment deteriorated. Also, since heat treatment is carried out separately, efficiency and productivity were low. Further, it was impossible to prevent deposition soot or glass-like carbon and to form a durable sliding treated layer that is low in friction coefficient.

According to Applicants' invention, since plasma carburizing is carried out at a low temperature of not more than 690°C in an atmosphere where the molar ratio is $1 \leq H/C \leq 9$, soot or glass-like carbon is less likely to deposit on the surface of the titanium metal due to a low carbon concentration. Thus, it is possible to turn many carbon atoms to solid solution on the surface to the limit of the α-type titanium metal, utilizing the effect of the aging treatment. This make it possible to form a relatively thick, durable sliding treated layer on the surface the titanium metal.

For these reasons, the subject matter of claims 1 and 2 is clearly patentable over Sato et al.

Therefore, in view of the foregoing amendments and remarks, it is submitted that the ground of rejection set forth by the Examiner has been overcome, and that the application is in condition for allowance. Such allowance is solicited.

Respectfully submitted,

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July 24, 2006